UNPACKING THE DUALITY OF DESIGN SCIENCE

Completed Research Paper

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Abstract

Much of the work within the information systems discipline has an implied focus on the science aspect of the area of research known as design science. However, the design aspect is often regarded as an obvious and straightforward activity. To the contrary, design is a complex and creative human activity that arises in many different disciplines, including architecture and engineering. This research focuses on articulating the significance of "design" in design science research. It proposes a 3-layer framework that clarifies the relationship between design and research. This framework provides the basis for developing a set of guidelines that helps distinguish different levels of design and research and highlights the knowledge goals for each level. Doing so unpacks the dual notions of design and science in a way that illuminates the design aspect within design science research, leading to a deeper understanding of how to conduct and apply such research.

Keywords: Design science, design process, architecture, design knowledge, patterns, framework, guidelines, designer, rigor and relevance

Introduction

Research in design science recognizes the effort undertaken by researchers attempting to analyze and understand problems of a "wicked" nature that are addressed by creating and evaluating artifacts. However, in the struggle to establish rigor in information systems design science research, the focus on the science component has eclipsed the important role of the design component. Design has its fundamental notions and principles rooted in other academic fields such as architecture, which have existed for a long time (Court, 1997; Groat & Wang, 2002). Design is, of course, both a noun and a verb. In this paper, we refer to design as a verb.

Design science as its name implies, incorporates a duality between design on one hand and science on the other. Recognizing both the design and science aspects of this kind of research indicates that there is a need to understand both of these aspects and their roles in order to appreciate their duality and, thus, how each can contribute to meaningful work in design science. The science-centric view is most commonly reflected in the IS literature and generally recognizes knowledge as a more collective and shared property.

This science-centric view marginalizes the fundamental primacy of the designer's knowledge, widely acknowledged in the design literature.

The objective of this research, therefore, is to analyze this duality of design science research in information systems by applying the fundamentals of design principles in root design disciplines such as architecture. The contribution of this work arises from the deeper understanding of the interplay between collective knowledge (privileged in the scientist view) and individual knowledge (privileged in the designer view). This understanding enables us to discover and articulate multiple levels of design science research, each with its own domain, purpose and goals. This, in turn, clarifies the differences between different kinds of research that inhabit the design science paradigm, and helps clarify their alternative forms.

This research compares the different ways in which design activities apply knowledge using the terminology found in the research literature. For example, the terms "design science" and "design research" are often used synonymously, making it no longer practical to distinguish these terms in any universal way.

As a discipline, design research can be traced back to the study of design methods in the early 1960's with roots in operations research (Cross, 2007). Design science is usually grounded on Simon's (1996) *Science of the Artificial*. Within a decade of these developments, some of these founders grew critically concerned that design was becoming over-rationalized by the focus on methodology and the scientific (Cross 2007).

Within the field of information systems, it is timely to review recent progress in design science developments from a similar critical perspective. Drawing from other applied design sciences, such as architecture and engineering, we find that it is important to retain a balanced respect for both the role of science, and the role of the designer's knowledge in the creation of a designed artifact. Design science combines design theory and design knowledge. The contribution of this research is to elucidate the role of "design" in design science, thus articulating and unpacking the design aspect from the science aspect to derive a 3-level framework for defining the relationship between design and research. A more parsimonious understanding of this relationship will help design researchers to more clearly set their objectives and identify their knowledge requirements when planning and conceptualizing their design research process.

This paper proceeds as follows. First we explain the duality in design science research that is represented by the relationship between design and knowledge. We anchor this explanation to concepts known in the fields of architectural design, knowledge management, software engineering, and theory development. Because design knowledge emerges as a key component of the design process, we then develop a framework explicating three levels in the knowledge relationship of design and research. Based upon this framework, we identify a set of nine guidelines for guiding the design activity at each of these three levels of design science research.

Design and Knowledge

The study of design is much older and widely developed than design science. Even for design narrowed information systems, an encyclopedic review of design is beyond the scope of a single article. Major areas of interest include: design involving the cooperation or participation of users (e.g. Ehn 1988; Kensing 2003; Kyng 1991; Mumford and Weir 1979); designing systems for practical usefulness (e.g. Norman 1983; Norman 1988); and design thinking, creativity, and innovation (e.g. Brown 2008; Papantonopoulos 2004; Wylant 2008). Most observers of the design process recognize it is messy or disorderly: difficult, multi-dimensional, and problematic. It defies an easy description, such that design process reviews in software engineering often represent a "faked rationality" (Parnas and Clements 1986).

One fundamental way to study design is to understand and analyze how central the designer's knowledge is to the design process (e.g. Tiwana and Ramesh 2001). This is because knowledge is fundamental to design processes, regardless of whether the processes are analytic or synthetic; symbolic or real; based on theory or based on practice. Furthermore, there are different ways to classify the many forms of knowledge. Owen (1998), for example, separates design knowledge into analytic versus synthetic as shown in Figure 1. Then, it becomes obvious that knowledge building and knowledge use are the key design activities leading to discovery and invention.

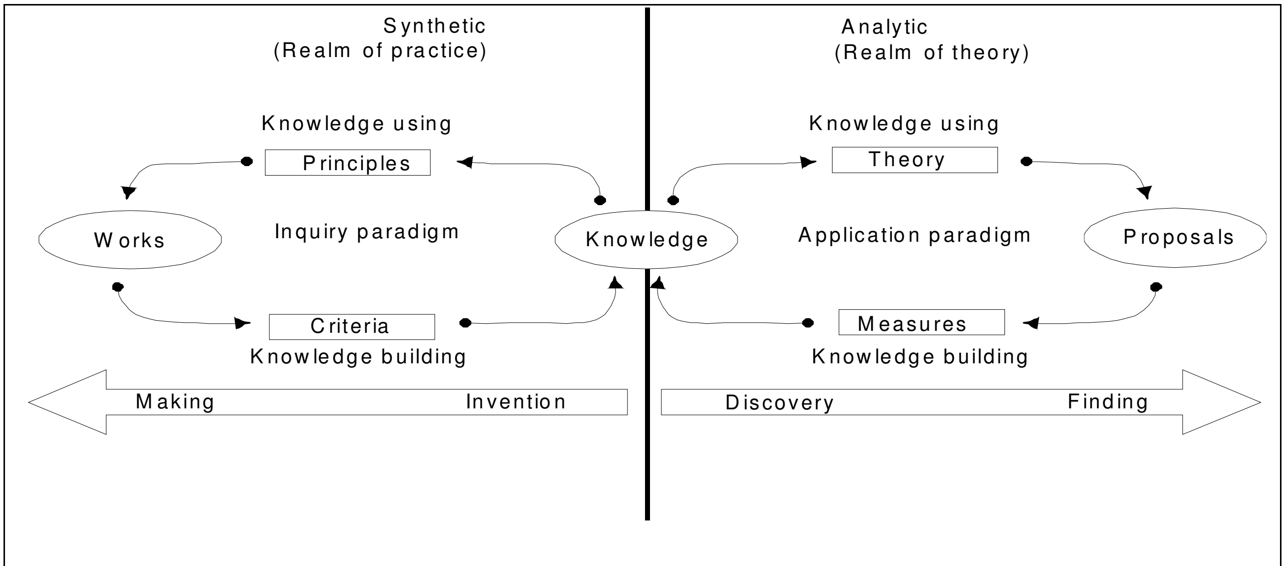

Figure 1. Design knowledge (from Owen 1998)

Because of its generative and creative aspects, no design activity can be carried out without knowledge being central. This centrality also extends to the kind of analytical design process embodied by heuristic design such as that described by Van Aken's adaptation of technological rules to design practice. Even within the design science research framework of rigor versus relevance, as shown in Figure 2, the role of knowledge is important. However, comparing Figure 1 with the more scientific orientation in Figure 2 (Hevner 2007) demonstrates how the centralization of knowledge is a distinction between the design aspect and the science aspect of design science research. In the latter, a collective scientific, knowledge is marginalized, whereas construction and evaluation becomes central. In the former, a more individual knowledge is centered, while construction is marginalized. This contrast in the centrality of making versus the centrality of designer knowledge embodies a contrast between the design view and the science view encapsulated by design science research. It is an important duality that helps shape design science research as a paradigm.

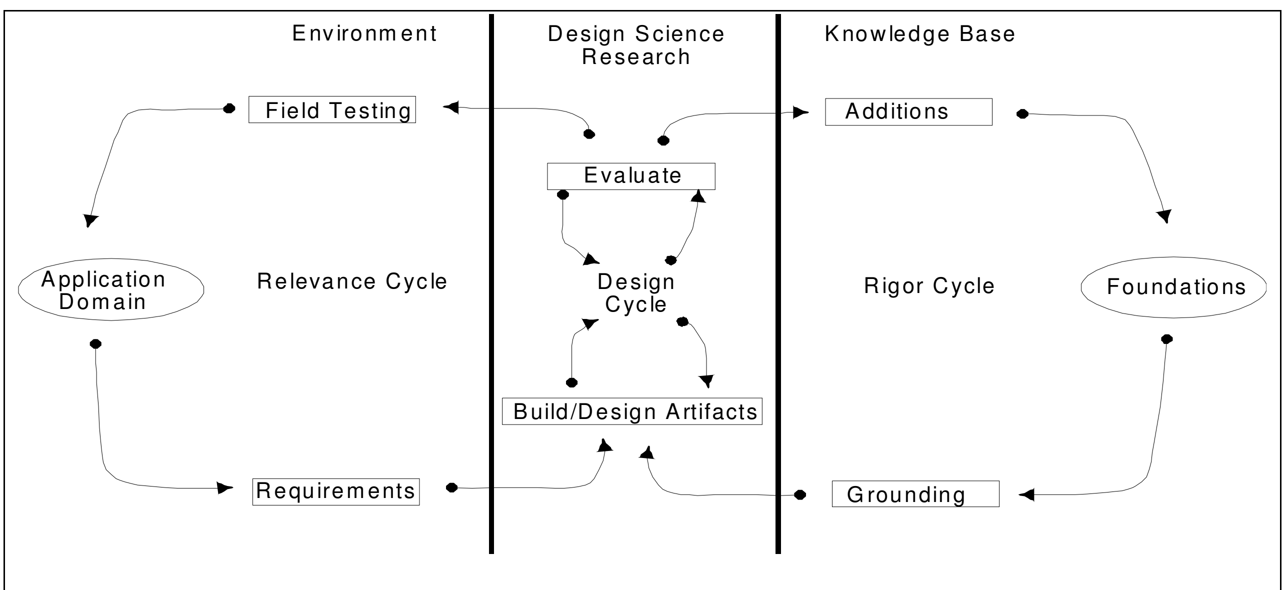

Figure 2. Three cycle view of design science research (from Hevner 2007)

Perhaps because of the need to establish rigor in design science research, there is much work in information systems in which the science-centric view is the principal aspect of the duality. Many researchers in information systems have undertaken efforts to formalize the main concepts and requirements for design science research within the information systems community (e.g. Gregor 2006; Hevner et al. 2004; March and Smith 1995; Markus et al. 2002; Nunamaker et al. 1990/1991; Purao 2002; Vaishnavi and Kuechler 2004; Walls et al. 1992). There is certainly also a prodigious body of information systems research on design (e.g., Brooks 2010; Churchman 1971; Coyne 1995; Gause and Weinberg 1989; Kensing 2003; Mumford and Weir 1979). Perhaps because this design aspect is taken-for-granted in design science research, there is very little work that elaborates design within the design science research context. There is a need to bring this work into some balance with a design-centric view. A starting point is to "unpack" this duality, by analyzing the design-centric view that currently exists as the marginalized, non-principal aspect of the duality.

Design Activity

Design activity is a complex task. Ralph and Wand (2009) provide an extensive analysis of some 30 definitions of design (as a verb), uncovering elements such as creation, planning, organizing and optimizing. It is a goal-driven human activity inhabited by requirements and constraints. It involves understanding the problem requirements, utilizing the designers' knowledge and experience, evaluating alternatives and formulating a design solution. The role of knowledge in the design process is ubiquitous. Knowledge serves as both the input to and the outcome of the design activity. Thus, the design activity relies upon the application of the designers' knowledge of the design domain, design process and design strategies as well as their experience and creativity in providing the best design solution, based upon the requirements, existing solutions, and constraints.

The design process itself helps augment the designers' existing knowledge and experience with the knowledge and experience gained during the design activity. Thus, in addition to a design solution, the outcome of the design experience is also the creation and acquisition of knowledge. Figure 3 represents the relationship between design and knowledge. It shows the design activity and the pervasiveness of knowledge in the design process. It also indicates how the designer draws upon and applies knowledge and how knowledge is created as an outcome of the design activity. A designer, when presented with a design task, participates in the design activity which involves him/her relying on previous domain experience as well as the process knowledge the designer possesses, knowledge from other domains and general knowledge. In addition, the designer can draw upon domain theories, design patterns, design rationales, which are discussed below.

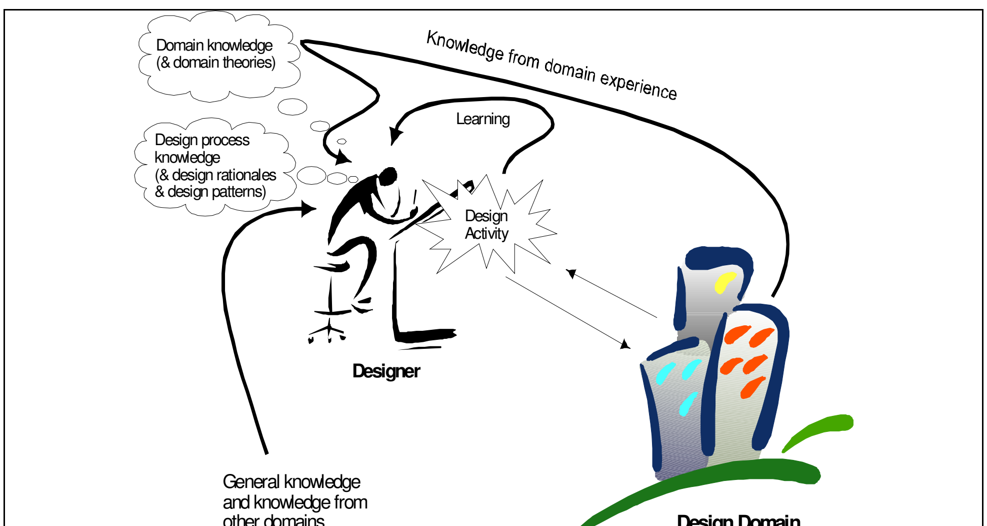

Figure 3. Relationship between Design and Knowledge

Designer Knowledge

Designer knowledge forms the basis of the designed artifact and is brought into the design activity by the designer, making it crucial to the design process. "The underlying axiom of the (design) discipline is that there are forms of knowledge special to the awareness and ability of a designer, independent of the different professional domains of design practice" (Cross 1982, p. 224). The significance of the designer's role in design has been explicitly acknowledged in architecture (Groat and Wang 2002).

Engineering design knowledge is held by the designer is a result of an appreciation of the area and environment in which the designer works (Ferguson 1992). For engineering design, the knowledge concepts are generated from inventions, theoretical engineering research, and experimentation and trials, whereas practical considerations arise from design practice, production, and trial (Vincenti 1990).

Since the research reported in this paper is inspired by an architectural and engineering perspective, it focuses on the significance of the "design" component of design science, which is based upon the design knowledge held by the designer. Depending on the individual involved, different types of knowledge can to be brought to the design activity for the design domain.

Design activity is tightly related to human creativity and innovation. This may be why research into the design activity centralizes the designer's knowledge. There are many different design knowledge concepts, each of which has been applied in different ways and for different purposes (Ralph and Wand 2009). There can also be many kinds of design knowledge. Architectural and engineering thought commonly identifies at least three distinct kinds of design knowledge (Court 1997; Ullman 1992). Designer knowledge includes: 1) General knowledge, 2) knowledge about the domain in which the designer is working, and 3) design process knowledge. These categories are drawn mainly from work in architectural and engineering design research (Court 1997; Groat and Wang 2002; Ullman 1992) and form the basis for our framework.

This is not an exhaustive list of the kinds of design knowledge required in information systems design. However, the foundations in architectural research, engineering, and information systems suggest that these categories are at least among the most important kinds of knowledge that should be taken into consideration. Because these design knowledge categories are entailed in information systems design, these are also necessarily entailed in the design aspect of design science research. When considered collectively, they portray the central role of design knowledge in the design activity. Each of these categories and their significance to design science is described below.

General Knowledge

Designers gain this kind of knowledge through everyday experiences and their general education. While each individual's general knowledge is different, it is often knowledge that is shared with a wide variety of other individuals who apply this knowledge in many diverse domains. For example, the designer of a taxi dispatching system will possess general knowledge gained as a passenger in taxis, knowledge about motor vehicles, traffic laws, general knowledge about driving, etc.

It is important to recognize general knowledge because it contributes to the individual traits of the designer. However, it is tangential to our purpose in this paper. It is beyond our scope to delve into any detailed analysis of the of designer's general knowledge.

Domain Knowledge

Every design setting involves a domain, or sphere of knowledge, influence or activity. The scope of this domain is highly situational. For example, a design domain could encompass computer software for dispatching taxis to origins and destinations. Into this design domain, every designer brings a different background.

Designers gain this kind of knowledge through their study of, and their experience with the specific design domain. Again, each designer's domain knowledge is individual, but related to the design of the technical system for the problem at hand. Such knowledge is often shared with others working in the design domain, even with those who are not involved in the design activity. For example, the designer of a taxi dispatching system may develop knowledge about vehicle route identification, geographic locations with high passenger density, vehicle fleet refueling and maintenance contracts, etc. Such domain knowledge is also likely found among taxi drivers and taxi managers. Because the domain includes computer software, the domain knowledge extends to operational knowledge about hardware and software products in the area, taxi electronic products, and even software behavior. Such domain knowledge might be shared with computer programmers or operators involved in taxi systems.

Design Domain Theories

Designers often draw on specific theories about their design domains. Design domain theory is a hybrid theory that bridges cognitive science and software engineering and can be used in conjunction with the design of information systems (Sutcliffe and Maiden 1998). Design domain theory "aims to assist design for reuse by providing a set of abstract models to guide analysis and assist design for reuse with design rationale and generic requirements" (Papamargaritis and Sutcliffe 2004, p. 110). Moreover, information systems design domain knowledge often extends to the application domain. For example, designing an accounting information system requires domain knowledge in accounting theory. Designing a manufacturing requirements planning information system requires domain knowledge in manufacturing operations theory.

Domain theory contends that design knowledge lies within the cognitive ambit of the individual. The experiential backgrounds of the designers link directly to their design contributions. More experienced designers are able to contribute more; less experienced designers contribute less. Domain knowledge combines knowledge and experience acquired through practice over a period of time. The accrued knowledge can be abstracted into a generic form and reused (Prieto-Diaz 1990). This provides the link to domain theory, which also presumes a similar experiential rationale for design expertise (Sutcliffe and Maiden 1998).

Design Process Knowledge

Developing design plans depends on the designer's prior experience with the design solution and the designer's ability to associate pre-existing plans and the design problem at hand (Robillard 1999). Designers gain this kind of knowledge through their study of, and experience with, the task of designing within a given enterprise. While individual designers will differ in their exact knowledge about the design process, it would be shared with others who engage in making similar designs. Design process knowledge is related to the design process at hand (knowledge about a general strategic approach to designing, knowledge about tactics and methods for designing, knowledge about design processes, knowledge about using working means, knowledge about previous design outcomes, etc.). For example, the designer of a taxi dispatching system will have knowledge about the procedure and process for making software designs, such as the process of making UML diagrams, flowcharts, scenarios, etc. Such process knowledge might be shared with other software designers, even those working in design domains other than taxi dispatching.

Design Rationale

The design process usually involves explicit or implicit design rationales. These define the basis of design of an artifact. "Design rationales include, not only the reasons behind a design decision, but also the justification for it, the other alternatives considered, the tradeoffs evaluated, and the argumentation that led to the decision" (Lee 1997, p.78). It is important in explaining why design has its characteristics and why some features are included in a design and others are not. Recording the chain of design decisions leading to the development of software provides a better understanding of the software, thereby enabling effective re-use of software components (Prieto-Diaz 1990). Design rationales assist in the decision making process and in reducing the time required for future development. According to Lee (1997), design rationales help provide "greater design support, … aid in design re-use and ultimately provide a learning tool for evaluating design". Thus, design rationales are an invaluable aid during the design process and subsequent to it. The need to record the reasoning behind design decisions includes a "generic model for representing design decisions" (Potts and Bruns, 1991). There has been sustained interest and efforts by both researchers and practitioners in researching, extending and refining frameworks, models, and tools pertaining to design rationales (Conklin and Yakemovic 1991; Klein 1993; Kruchten et al. 2006; Potts 1996; Ramesh and Dhar 1992; Shum and Hammond 1994). Oinas-Kukkonen (1998) provides a representative example of research design of a design rationale tool.

Design Patterns

In the process of the design activity, designers draw upon their knowledge, experience, and expertise of the design domain. A large proportion of design activity, therefore, includes reusing and reworking existing designs. In information systems, such knowledge about previous designer outcomes exists prevalently in the form of design patterns (Fach 2001; Vaishnavi and Kuechler 2007). Patterns are well-accepted and effective in software engineering because such knowledge is gained through design experience an can be reused for new designs through the structural specification of system architectures (Shaw 1991). The basic notion is that there are fundamental elements in designs. A design pattern names, labels, abstracts, and identifies the key aspects of a common design structure that make it useful for creating a reusable object-oriented design (Gamma et al. 1995).

At its simplest level, design patterns are metaphors for a reusable behaviors and structures that have occurred in previous design activities (Fach 2001). Patterns invite experiential reuse that provides the link to design knowledge. Patterns do not require limitation of the designer's creativity (Goel 1997; Schmidt et al. 1996), nor do they require the automation of design. Instead, they emphasize the aspects that are quintessential to human knowledge transfer. The idea of re-use of the elements of the design itself is a desirable one. For example, Service Oriented Architecture is a high-level design architecture aimed at providing reuse to developers. The services one chooses could have patterns that are related (Schmidt 1995).

Summary

The three-category classification of designers' knowledge is usefully simple, but of course not exhaustive, nor mutually exclusive with any rigor. For example, in some analyses, design process knowledge can be regarded as the combination of general and domain knowledge (Ullman 1992). However, the terminology does allow us to improve our understanding of three levels in the relationship between design and research in design science research. These three types of design related knowledge are summarized in Table 1. The table also provides a brief description and an example.

Table 1: Classification of Designer Knowledge

Types of Design Knowledge	Description	Examples
General Knowledge	Gained from everyday experience	A software designer is called to develop a banking system for a bank in the U.S. His/her knowledge as a consumer of the banking domain (e.g. personal bank accounts) demonstrates general knowledge.
	Acquired by the non-expert in the design domain	
Domain Knowledge	Gained from study/ experience in specific design domain	To design a banking system, the designer needs to possess domain-specific knowledge about the processing of bank transactions, the organization of bank operations, and perhaps extending to operational computing knowledge such as programming and database principles.
	Acquired by the expert in the design domain	
Design Process Knowledge	Gained from training or experience designing	To design a banking system, the designer needs to know how to go about making system designs, the definition of requirements and their translation into software specifications. The designer must know about the process of making such a design.
	Acquired by designers for the design tasks at hand.	

Design and Research

Information systems, like many other disciplines, take for granted the distinction between practice and research (Robey and Markus 1998). Research approaches such as action research and design science blur these distinctions by integrating the two activities. Information systems design science, like architecture, recognizes two different ways relate design and research. For example, in architecture, Groat and Wang (2002) distinguish design-as-research from research-about-the-design-process. In the former, in a mode quite similar to action research, we use the venue of a design problem as a means for studying the problem and the grounds for its solution. In the latter, we inquire into the design activity in order to understand design processes (Groat and Wang 2002).

However, architecture also recognizes a third relationship between research and design that is not as well recognized in information systems. This relates research to design as a practical means to improve the design outcome. Its prevalent form in architecture is known as environment-behavior research (Zeisel 2006) or architectural programming (Mittleman 2009). Designers use rigorous research methods in a disciplined inquiry into the mission and objectives of the relevant people in order to “program” an efficient and functional built environment (Preiser 1985). Designers organize “their inquiry as research and their design as inquiry” using primary methods such as “observing people and environments, asking questions in interviews and questionnaires, and using data and plan archives” (Zeisel 2006, p. 14). Research-as-a-means-for-design is present in IS practice in the form of scientifically rigorous requirements analysis (e.g. Kelder and Turner 2005, discussed below), along with design science work in which researchers and designers often collaborate (e.g. Aaen 2008; Weedman 2008).

These distinctions are represented in Table 2 as a three-level taxonomy of design activities (as related to research activities). Although there are multiple ways to consider the relationship between design and research, understanding and analyzing these should lead to useful guidelines for carrying out research that focuses on design.

- Level 1: Designing with Research (research-as-the-means-for-design) (Zeisel 2006)
- Level 2: Research into Design (research-about-the-design-process) (Groat and Wang 2002)
- Level 3: Design as Research Methodology (design-as-research) (Groat and Wang 2002)

These levels are based upon the degree of research as the output of the design process, in relation to the degree of the design activity that produces scientific knowledge. At Level 1, the significant overall output is the result of the design activity that produces domain knowledge. At Level 2, the significant overall output is rather balanced, producing research about the design activity and adding to design process knowledge. Simon’s work is an example of Level 2. At Level 3, the significant overall output is the result of the research activity and enhances domain knowledge. Each level is described and exemplified in more detail below.

Table 2. Three-Level Design framework

	Level 1 Designing with Research	**Level 2 Research Into Design**	**Level 3 Design as Research Methodology**
Research Domain	Design domain	Design process	Usually design domain
Purpose	Produce good designs	Understand design activity	Understand research domain
Primary Knowledge Goal	Domain knowledge	Design process knowledge	Domain knowledge
Example	(e.g. Kelder and Turner 2005)	(Ehn et al. 1996)	(Vaishnavi et al. 1997)

Level 1: Designing with Research

At this level, the design domain is the research domain. The central aim of designing with research is usually the goal of building something for a social or practical purpose or to enhance design knowledge. Designing with research is carried out by experienced and enlightened designers in order to improve their fundamental designs and to deliver the best possible outputs for design. Research is conducted to provide a scientific basis for the fundamental principles on which the design is founded to ensure that these are well grounded. This helps strengthen the fundamentals of the design through a search into the background on which the research is based. Discerning and enlightened designers are able to take these inputs and use them to illuminate the domain of the design. In designing with research, the designer brings his/her own general and design process knowledge, combines them with domain knowledge and uses a combination of scientific principles and creativity to generate a design solution based upon the requirements. As a result, domain knowledge is enhanced.

An example that illustrates Level 1 is the research into the work of weather forecasters as a prelude to the design of a meteorological information system. In this example, Kelder and Turner (Kelder and Turner 2005) conducted cognitive ethnographical research leading to the discovery of the distributed cognitive nature of weather forecasting. They learned how forecasters communicated and employed symbolic and mediating structures in their particular situations. These discoveries enabled the designers to avoid the techno-centric design trap that arises from design-for-users rather than design-for-humans (Gasson 2003).

At this level, research regards the design domain, and it means the ethnographic research domain was the same as the design domain. This example shows how designers bring their general, domain, and design process knowledge into their design activity and takeaway additions to their domain knowledge.

Level 2: Research into Designing

At this level, the pursuit of design knowledge is more from an academic, rather than a practice perspective. The research domain is distinct from the design domain in that the process of design is studied in order to understand and improve the design activity. Its purpose is to illuminate the design activity, creating scholarly knowledge about the human process of designing (design process knowledge). This relationship does not define a research methodology, but rather a research topic. Consequently, it is open to the use of nearly all research paradigms and nearly any research methodology. It may undertake the research of research-based design or practitioner-based design. Research into design may draw from parallel design fields and may study the design methodology, the actual design constructs, or the implications of design. Research into design can be undertaken by researchers studying the design domain or by designers who intend to use the knowledge gained to improve their designs.

"The Envisionment Workshop" project (Ehn et al. 1996) is an example of Research into Design. This laboratory provided a design forum for participatory research where designers and architects worked collaboratively with users to develop realistic future workplaces using techniques such as prototyping, 3D-animation, and modeling. The project researched design at the horizon of actual and virtual reality to produce "illuminated" visions of the future. This project highlights the process of research into design involving exploration of the design field in order to develop a higher level understanding of the procedure of design activity.

Level 3: Design as Research Methodology

Design as a research methodology is the use of design science as a means of creating domain knowledge about the design domain. Research is usually conducted in the design domain and is potentially interventionalist in nature. The potential for intervention arises in cases where the research leads, not only to a design outcome, but also to the instantiation of the design as an artifact that is introduced into the design domain. Such instantiations mean that design science research outcomes will resemble field experiments or action research. The research, design, and evaluation are influenced by the general and design process knowledge of the designer with the validation of the process often anchored to the practical value of the design. At this level, the research process and the design process merge, and result in knowledge about the design domain.

The Smart Object Paradigm (Vaishnavi et al. 1997) is an example of design as a research methodology. The researchers investigated this alternative as a means of reconceptualizing ways to achieve the functionality required of operations support systems. Part of their means for this investigation was the design and development of a Smart Object Language for the purpose of creating networks of smart objects that exchange data and control information. Following the ideals of this paradigm, knowledge is contained in the network and managed in relation to environments. The design of the language both embodies and exemplifies the paradigm. The design process was part of the discovery process leading to a workable Smart Object Paradigm.

The research and development of mid-range theory by Keuchler & Vaishnavi (2008) is another example of design as a research methodology. Here the authors have demonstrated the process of using design research to create knowledge pertaining to the design domain by refining and extending kernel theory to develop a mid-range Design Science Research theory thereby illuminating the design domain. The research domain in this case was the design domain and the purpose was to improve and produce knowledge pertaining to the design domain. Thus, it satisfies the three guidelines associated with Level 3 (Design as a research methodology).

Guidelines

The three levels provide a framework from which to derive a set of design guidelines for design science research where recognizing the level of the research can influence the effectiveness of the outcome. There are essentially three guidelines. The first deals with the proper relationship between the research domain and the design domain. The second is with regards to establishing the purpose of the design. The third is concerned with the primary knowledge goals. However, these three guidelines vary depending on the level of the research. Table 3 details the three versions of the guidelines.

Guideline 1: Design as the means or the end in the activities

The first guideline deals with the role of the design activity in research. At Level 1, research activities are motivated by the need to support the design activity. The design activity is paramount with the research activity a means to achieve a good design. The subject (the domain) of the design and the subject of the research are exactly the same. At Level 2, research activities grow more central, and are motivated by the need to understand the design activity. The subject of the design activity and the research activity are different. The design activity becomes the subject (the domain) of the research activity. At Level 3, design activities are motivated by the need to support the research activity. The subject of the design (the domain) will often (but not necessarily) be the subject of the research. The research domain may only be related in some way to the design domain, such that the research domain is available for study through the design activity. The research activity is paramount, and the design activity is a means to achieve a research outcome.

Guideline 2: Design as the product, the subject, or the vehicle

The second guideline deals with the role of the design outcome in relationship to research outcomes. At Level 1, the design outcome is the product of both research and design activities. This design outcome is the only major purpose in the work. At Level 2, the purpose of the work shifts from the achievement of the design activity, and shifts onto the design activity itself as the subject of the research activity. Design is no longer the product of both design and research activities. Rather, it is the subject of the research activity. At Level 3, the purpose of the work shifts mainly to the achievement of the research goals. Design activities become the vehicle for achieving research outcomes.

Guideline 3: Design knowledge contribution:

The third guideline deals with whether the design knowledge (the knowledge embodied in the design) is central in the work activity, or marginal. At Level 1, because the design outcome is the product of both research and design activities, the design knowledge and the research knowledge are the same. By definition, the design knowledge and the research knowledge outcome are equivalent. At Level 2, the actual outcomes of the design may indeed be marginal. The purpose of the work is to study the design activity. The design knowledge outcomes are equally marginalized by the research activities. At Level 3, because the purpose of the work shifts to the research aims, the design knowledge is also marginalized in the work activity. The main knowledge contributions are fastened on the research outcomes.

Table 3. Guidelines for the Design aspect of Design Science Research

Level	Guideline	Description
Level 1: Designing with Research	**Guideline 1:** The research domain should be the same as the design domain.	The domain of the main knowledge-producing activities of the research should be the same as the knowledge domain of the intended environment of the design products. The research should improve the useful value of the contemplated artifacts within its planned environment.
	Guideline 2: The purpose should be to produce good designs	The design outcomes should be valuable, tangible and coherent. The environment of the contemplated artifacts should be improved and the design problem should be resolved.
	Guideline 3: The primary knowledge goal should be to produce knowledge in the research/design domain.	The objective of designing with research is to have tangible outcomes in terms of delivery of domain knowledge. This knowledge contribution should be clear, succinct and measurable, and both distinct from, and yet incremental to, earlier efforts.
Level 2: Research into Design	**Guideline 1:** The research domain should be the design process.	The domain of the main knowledge-producing activities of the research should be the process of design and the activities of the designers. The research should improve the design processes themselves.
	Guideline 2: The purpose should be to understand design activities	The main objective is to illuminate and understand the activities of the designers engaged in making designs.
	Guideline 3: The primary knowledge goal should be to produce knowledge in the design process.	The objective of research into designing is to have tangible outcomes in terms of delivery of knowledge about the design process or the designers themselves. This knowledge contribution should be clear, succinct and measurable, and both distinct from, and yet incremental to, earlier efforts.
Level 3: Design as Research Methodology	**Guideline 1:** The research domain should usually be the same as the design domain.	The domain of the main knowledge-producing activities of the research should be the same as the knowledge domain of the intended environment of the design products. The research should improve the useful value of the contemplated artifacts within its planned environment.
	Guideline 2: The purpose should be to understand the research domain.	The significant outcome is the knowledge about the natural, social, or artificial environment, problem space, or artifacts intended for the design products. The objective is to understand and illuminate the knowledge domain of the intended environment of the design products.
	Guideline 3: The primary knowledge goal should be to produce knowledge in the research domain.	The objective of designing with research is to have tangible outcomes in terms of delivery of domain knowledge. This knowledge contribution should be clear, succinct and measurable, and both distinct from, and yet incremental to, earlier efforts. The researchers and designers draw upon general knowledge and design process knowledge to illuminate the design domain.

Discussion

This research is intended to aid researchers in understanding design and how it differs from other forms of science by unpacking the dual notions of design and science, thus bringing to the forefront, the important, yet often overlooked, aspect of design in design science research. Design is a complex activity. The unpacking helps to simplify this complexity by identifying the different levels of design and providing explicit guidelines for the design aspect of design science research. These guidelines are driven from the recognition of designer knowledge.

Much of the recent work in information systems design science research falls into Level 3, where design is used as a research activity. In particular, there may be an expectation that design science operates only at an abstract, general level, such that the design activity is operating on a class of problems and yielding a class of design outcomes (Walls et al. 1992). Design in the abstract is design nevertheless. However, if we establish this abstract/class notion as a definitional requirement for design science, we might exclude both Level 1 and Level 2 from the realm of design science. Such exclusion, however, will clearly not carry far, since the foundations of design research and the sciences of the artificial lay in such design studies. It is not logically possible to exclude design research and design science from itself.

The three design science levels relating design and research may indeed operate universally across a wide variety of different approaches to the science of design. This universality may arise because the relationship between design and research occurs whether the approach is focused on a general design for a class of problems (Walls et al. 1992), or more narrowly focused on a more singular or local problem (Järvinen 2007). This distinction has also been called macro versus micro design science approaches (Fischer 2011). Indeed, the notion of local design science (micro) is generally coherent with Level 1 (design with research) while problem-class oriented design science (macro) is generally coherent with Level 3 (design as research methodology). For example, van Aken (2004) promoted the use of technological rules as a form of management design science. Because these technological rules are more-or-less abstract or problem-class-oriented, their design is coherent with Level 3. This coherence supports van Aken's position that the design of technological rules is a form of design science with good potential for application in management.

The three level analysis of design science research may also have parallels with action research. For example, Level 1 (local or micro) action research is acknowledged as a primary means of practical organizational development and consulting (Lippitt and Lippitt 1978; Schein 1969). Level 3 (class-oriented or macro) action research is reflected in the original, and more theory-development-oriented form (Lewin 1947; Susman and Evered 1978). As with design science, there is also a considerable body of work about action in social settings (e.g. Schön 1983), that would qualify as Level 2.

The admission of Level 1 to the realm of design science is admittedly debatable. Level 1 is certainly a design study, but it does not necessarily operate with abstract/class kinds of elements. It deals with designing in a scientific manner, much like "scientific" management or "scientific" farming. It is a point at which science serves design practice. While it may be liberal to do so, any strong conceptualization of design science research needs at least to establish a placeholder in the margins for "scientific design".

This framework provides a way to compare the role of research in relationship to design and recognition of the role of design, which is fundamental to the design discipline and which has been studied extensively in other domains for a long time. The significance of knowledge is present in, but not central to, existing design science research (Hevner et al. 2004). The implications of this research are to articulate the significance of "design" in design science, to bring the notion of design to the forefront and to propose a framework which provides clarity regarding the relationship between design and research. This is useful from the perspective of researchers and designers as well as practitioners. This research can help researchers and designers determine the appropriate approach to their research through a parsimonious set of guidelines that relates process of design within design science. During the research planning and conceptualization process, these guidelines can help design researchers to set the objectives (the purpose) of the research in terms of its level. It will also help them to identify the knowledge requirements (their research domain). These guidelines also help researchers to condition their goals in keeping with the level at which they have planned and conceptualized their design research process.

One problem broached in the relationship between design and research is the conceptual union of different mental faculties. Design is often a creative and generative mental activity, while science is often deductive and analytical. It "subsumes a reality that is inherently non-propositional (generative design as a mode of art production) under the domain of a propositional activity (analytical research) which raises logical difficulties" (Groat and Wang 2002, p. 105-106). More research is needed to examine the potential logic problems at each of the three levels. Future research is also needed to empirically test the use of the nine guidelines in information systems design science research projects perhaps using available methodologies such as action design research (Sein et al. 2011) or soft design science (Baskerville et al. 2009). The work above also leads to further investigation and analysis of other key perspectives of design knowledge such as creativity, complexity and innovation.

Conclusion

With an increasing focus on research rigor, the important aspect of design in design science research has often become marginalized. This paper has investigated the significance of the design process, highlighting the role of designer knowledge in the design activity. Related areas of design, such as engineering and architecture, have heavily influenced the investigation. By doing so, this research unpacks and articulates the duality of the design and science aspects of design science and brings the importance of design into better balance with science. Key concepts such as design knowledge, domain theories, design rationales and design patterns have highlighted the importance of the designers' knowledge in the design process. Thus, the role of the designer, and his or her knowledge and experience, are instrumental in defining the overall design.

A three-level framework defines the relationship between design and research. Considering this relationship more closely is beneficial since it can narrow the gap between rigor and relevance, providing a theoretical basis for the pursuit and advancement of design science research relating to management information systems. Lastly, the insights from this investigation into the role of design lead to a useful set of research guidelines.

References

Aaen, I. 2008. "Essence: Facilitating Software Innovation," *European Journal of Information Systems* (17:5), pp. 543-553.

Baskerville, R., Pries-Heje, J., and Venable, J. 2009. "Soft Design Science Methodology " *Design Science Research in Information Systems and Technology DESRIST 2009,* J.J. Li and K. Mohan (eds.), Philadelphia, Pa: Association of Computer Machinery.

Brooks, F.P. 2010. *The Design of Design: Essays from a Computer Scientist*. Upper Saddle River, NJ: Addison-Wesley.

Brown, T. 2008. "Design Thinking," *Harvard Business Review* (86:6), pp. 84-93.

Churchman, C.W. 1971. *The Design of Inquiring Systems*. New York: Basic Books.

Conklin, E.J., and Yakemovic, K. 1991. "A Process-Oriented Approach to Design Rationale," *Human-Computer Interaction* (6:3), pp. 357-391.

Court, A.W. 1997. "The Relationship between Information and Personal Knowledge in New Product Development," *International Journal of Information Management* (17:2), Apr, pp. 123-138.

Coyne, R. 1995. *Designing Information Technology in the Postmodern Age: From Method to Metaphor*. Cambridge, Mass: MIT Press.

Cross, N. 1982. "Designerly Ways of Knowing," *Design Studies* (3:4), pp. 221-227.

Cross, N. 2007. "Forty Years of Design Research," *Design Studies* (28:1), pp. 1-4.

Ehn, P. 1988. *Work-Oriented Design of Computer Artifacts*, (2 ed.). Stockholm: Arbetslivscentrum.

Ehn, P., Brattgård, B., Dalholm, E., Davies, R.C., Hägerfors, A., Mitchell, B., and Nilsson, J. 1996. "The Envisionment Workshop - from Visions to Practice," in *Proceedings of the Participatory Design Conference*. Boston: MIT, pp. 141-152.

Fach, P. 2001. "Design Reuse through Frameworks and Patterns," *IEEE Software* (18:5), pp. 71-76.

Ferguson, E.S. 1992. *Engineering and the Mind's Eye*. Cambridge, MA, 1992: MIT Press.

Fischer, C. 2011. "The Information Systems Design Science Research Body of Knowledge – a Citation Analysis in Recent Top-Journal Publications"," *PACIS 2011 Proceedings*, Brisbane, p. Paper 60.

Gamma, E., Helm, R., Johnson, R., and J, V. 1995. *Design Patterns: Elements of Reusable Object-Oriented Software*. Boston: Addison-Wesley.
Gasson, S. 2003. "Human-Centered Vs. User-Centered Approaches to Information System Design," *JITTA : Journal of Information Technology Theory and Application* (5:2), pp. 29-46.
Gause, D., and Weinberg, G. 1989. *Exploring Requirements: Quality before Design*. New York: Dorset House.
Goel, A.K. 1997. "Design, Analogy, and Creativity," *IEEE Expert* (12:3), pp. 62-70.
Gregor, S. 2006. "The Nature of Theory in Information Systems," *MIS Quarterly* (30:3), pp. 611-642.
Groat, L., and Wang, D. 2002. *Architectural Research Methods*. New York: Wiley.
Hevner, A.R. 2007. "A Three Cycle View of Design Science Research," *Scandinavian Journal of Information Systems* (19:2), pp. 87-92.
Hevner, A.R., March, S.T., Park, J., and Ram, S. 2004. "Design Science in Information Systems Research," *MIS Quarterly* (28:1), Mar 2004, pp. 75-105.
Järvinen, P. 2007. "Action Research Is Similar to Design Science " *Quality and Quantity* (41:1), pp. 37-54.
Kelder, J.-A., and Turner, P. 2005. "People, Places and Things: Leveraging Insights from Distributed Cognition Theory to Enhance the User-Centered Design of Meteorological Information Systems," *JITTA : Journal of Information Technology Theory and Application* (7:1), pp. 77-92.
Kensing, F. 2003. *Methods and Practices in Participatory Design*. Copenhagen: ITU Press.
Klein, M. 1993. "Capturing Design Rationale in Concurrent Engineering Teams," *Computer* (26:1), pp. 39-47.
Kruchten, P., Lago, P., and van Vliet, H. 2006. "Building up and Reasoning About Architectural Knowledge," in *Quality of Software Architectures,* C. Hofmeister, I. Crnkovic and R. Reussner (eds.). Berlin / Heidelberg: Springer, pp. 43-58.
Kuechler, B., and Vaishnavi, V. 2008. "On Theory Development in Design Science Research: Anatomy of a Research Project," *European Journal of Information Systems* (17:5), pp. 489-504.
Kyng, M. 1991. "Designing for Cooperation: Cooperating in Design,," *Communications of the ACM* (34:12), pp. 65-73.
Lee, J. 1997. "Design Rationale Systems: Understanding the Issues," *IEEE Expert* (12:3), pp. 78-85.
Lewin, K. 1947. "Frontiers in Group Dynamics," *Human Relations* (1:1), pp. 5-41.
Lippitt, G., and Lippitt, R. 1978. *The Consulting Process in Action*. San Diego California: University Associates.
March, S.T., and Smith, G.F. 1995. "Design and Natural Science Research on Information Technology," *Decision Support Systems* (15:4), Dec 1995, pp. 251-266.
Markus, M.L., Majchrzak, A., and Gasser, L. 2002. "A Design Theory for Systems That Support Emergent Knowledge Processes," *MIS Quarterly* (26:3), pp. 179-212.
Mittleman, D. 2009. "Planning and Design Considerations for Computer Supported Collaboration Spaces*," *Journal of the Association for Information Systems* (10:3), pp. 278-305.
Mumford, E., and Weir, M. 1979. *Computer Systems Work Design: The Ethics Method*. London: Associated Business Press.
Norman, D. 1983. "Design Rules Based on Analysis of Human Error," *Communications of The ACM* (26:4), pp. 254-258.
Norman, D. 1988. *The Pyschology of Everyday Things*. New York: Basic Books.
Nunamaker, J.F., Chen, M., and Purdin, T.D.M. 1990/1991. "Systems Development in Information Systems Research," *Journal of Management Information Systems* (7:3), pp. 89-106.
Oinas-Kukkonen, H. 1998. "Evaluating the Usefulness of Design Rationale in Case," *European Journal of Information Systems* (7:3), Sep, pp. 185-191.
Owen, C.L. 1998. "Design Research: Building the Knowledge Base," *Design Studies* (19:1), pp. 9-20.
Papamargaritis, G., and Sutcliffe, A. 2004. "Applying the Domain Theory to Design for Reuse," *BT Technology Journal* (22:2), pp. 104-115.
Papantonopoulos, S. 2004. "How System Designers Think: A Study of Design Thinking in Human Factors Engineering," *Ergonomics* (47:14), pp. 1528-1548.
Parnas, D., and Clements, P. 1986. "A Rational Design Process: How and Why to Fake It," *IEEE Transactions on Software Engineering* (SE-12:2), pp. 251-257.
Potts, C. 1996. "Supporting Software Design: Integrating Design Methods and Design Rationale," in *Design Rationale: Concepts, Techniques, and Use,* T.P. Moran and J.M. Carroll (eds.). Boca Raton: CRC Press, pp. 295-321.
Preiser, W.F.E. (ed.) 1985. *Programming the Built Environment*. New York: Van Nostrand Reinhold.

Prieto-Diaz, R. 1990. "Domain Analysis: An Introduction," *ACM SIGSOFT Software Engineering Notes* (15:2), pp. 47-54.

Purao, S. 2002. "Design Research in the Technology of Information Systems: Truth or Dare," The Pennsylvania State University and State Georgia State University, State College Penn and Atlanta Ga, p. 48.

Ralph, P., and Wand, Y. 2009. "A Proposal for a Formal Definition of the Design Concept," in *Design Requirements Engineering: A Ten-Year Perspective,* K. Lyytinen, P. Loucopoulos, J. Mylopoulos and B. Robinson (eds.). Berlin: Springer, pp. 103-136.

Ramesh, B., and Dhar, V. 1992. "Supporting Systems Development by Capturing Deliberations During Requirements Engineering," *IEEE Transactions on Software Engineering* (18:6), pp. 498-510.

Robey, D., and Markus, M.L. 1998. "Beyond Rigor and Relevance: Producing Consumable Research About Information Systems," *Information Resources Management Journal* (11:1), pp. 7-15.

Robillard, P.N. 1999. "The Role of Knowledge in Software Development," *Communications of the ACM* (42:1), pp. 87-92.

Schein, E. 1969. *Process Consultation: Its Role in Organizational Development*. Reading, Mass: Addison-Wesley.

Schmidt, D.C. 1995. "Using Design Patterns to Develop Reusable Object-Oriented Communication Software," *Association for Computing Machinery. Communications of the ACM* (38:10), Oct, pp. 65-74.

Schmidt, D.C., Fayad, M., and Johnson, R.E. 1996. "Software Patterns," *Communications of the ACM* (39:10), pp. 37-39.

Schön, D. 1983. *The Reflective Practitioner: How Professionals Think in Action*. New York: Basic.

Sein, M.K., Henfridsson, O., Purao, S., Rossi, M., and Lindgren, R. 2011. "Action Design Research," *MIS Quarterly* (35:2), pp. 37-56.

Shaw, M. 1991. "Heterogeneous Design Idioms for Software Architecture," in *Proceedings of the Sixth International Workshop Onsoftware Specification and Design*. pp. 158-165.

Shum, S.B., and Hammond, N. 1994. "Argumentation-Based Design Rationale: What Use at What Cost," *International Journal of Human-Computer Studies* (40:4), pp. 603-652.

Susman, G., and Evered, R. 1978. "An Assessment of the Scientific Merits of Action Research," *Administrative Science Quarterly* (23:4), pp. 582-603.

Sutcliffe, A., and Maiden, N. 1998. "The Domain Theory for Requirements Engineering," *IEEE Transactions on Software Engineering* (24:3), Mar, pp. 174-196.

Tiwana, A., and Ramesh, B. 2001. "A Design Knowledge Management System to Support Collaborative Information Product Evolution," *Decision Support Systems* (31:2), Jun, p. 241.

Ullman, D.G. 1992. *The Mechanical Design Process*. New York: McGraw-Hill.

Vaishnavi, V., and Kuechler, W. 2004. "Design Research in Information Systems." Retrieved October 2, 2004, from http://www.isworld.org/Researchdesign/drisISworld.htm

Vaishnavi, V.K., Buchanan, G.C., and Kuechler, W.L. 1997. "A Data/Knowledge Paradigm for the Modeling and Design of Operations Support Systems," *IEEE Transactions on Knowledge & Data Engineering* (9:2), pp. 275-291.

Vaishnavi, V.K., and Kuechler, W. 2007. *Design Science Research Methods and Patterns: Innovating Information and Communication Technology*. New York: Auerbach Publications.

van Aken, J.E. 2004. "Management Research Based on the Paradigm of the Design Sciences: The Quest for Field-Tested and Grounded Technological Rules," *The Journal of Management Studies* (41:2), pp. 219-246.

Vincenti, W.G. 1990. *What Engineers Know and How They Know It: Analytical Studies from Aeronautical Engineering*. Baltimore: John Hopkins University Press.

Walls, J.G., Widmeyer, G.R., and El Sawy, O.A. 1992. "Building an Information System Design Theory for Vigilant Eis," *Information Systems Research* (3:1), pp. 36-59.

Weedman, J. 2008. "Client as Designer in Collaborative Design Science Research Projects: What Does Social Science Design Theory Tell Us?," *European Journal of Information Systems* (17:5), pp. 476-488.

Wylant, B. 2008. "Design Thinking and the Experience of Innovation," *Design Issues* (24:2), pp. 3-14.

Zeisel, J. 2006. *Inquiry by Design: Environment/Behavior/Neuroscience in Architecture, Interiors, Landscape, and Planning*. New York: Norton.